Angle of attack of center of mass during the running of an entire 100m dash

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The angle of attack is related to the body posture and changes during sprinting because of changes in the horizontal velocity. The aim of this study was to analyze the angle of attack of the center of mass and the horizontal velocity during a 100 m dash. Twelve video cameras were positioned along a running track to obtain the position of the center of mass. The horizontal velocity was derived from the position data. When the different sides were compared, the angles were lower on the right side than on the left side ($P < 0.05$), which tended to decrease with increasing horizontal velocity. The results show the variability of the angle of attack as associated to the horizontal velocity, and the differences considering laterality

KEYWORDS: Kinematic analysis, biomechanics, multiple cameras, outdoor track

INTRODUCTION: Kinematic analysis can be used to describe movement and obtain information related to sports performance. For sprinting, the horizontal velocity is an important variable that affects the performance, and its association with different variables may interfere in the dynamics of a race. This can change movement patterns sand thus influence the outcome.

The angle of attack characterizes the body posture and movement patterns (Kugler & Janshen, 2010) and is mainly modified during sprinting by changes to the horizontal velocity.

The relationship between the attack angle of the center of mass and the horizontal velocity during running has already been explored in studies on mechanical models of gaits and running (Knuesel, Geyer & Seyfarth, 2005; Garcia et al., 1998).These variables have an inverse behavior: During running, the horizontal velocity increases as the angle of attack decreases (Knuesel, Geyer & Seyfarth, 2005).

Usually, in mechanical models and simulations, the angle of attack is usually fixed to stabilize running patterns. In their simulation, Seyfarth et al. (2002) used a fixed angle of attack in order to assess their robot’s movement. However, this is an ideal situation that does not occur in the movement patterns of sprinters.

This relationship between the angle of attack and horizontal velocity under real conditions is unexplored and may provide important information about the modality. Thus, the aim of this study is to analyze the angle of attack of the center of mass and the horizontal velocity during 100 m dash, in a training situation on an outdoor track. Better understanding of this relationship may help coaches identify how the horizontal velocity interferes with the movement patterns of an athlete.

METHODS: Five elite male sprinters agreed to participate in this study. Their mean age, height, and weight were 20±2.5 years, 1.76±0.05 m, and 72.06±6.9 kg, respectively. The experimental procedure consisted of a maximal sprint over 100 m on an outdoor running track. Twenty-one white markers with diameters of 40 mm were placed on the forearms, upper arms, head, trunk, pelvis, thighs, shanks, and head of the fifth metatarsal. The body center of mass was calculated based on the anthropometric model proposed by Zatsiorsky, Seluyanov & Chugunova (1990) and De Leva (1996).

Data were recorded with eight JVC (GZ-HD620BU) video cameras and four Casio (EXFH25) cameras at 60 Hz with a shutter speed of 1/2000. The set of cameras covered three regions (region 1: C1, C2, C5, C6; region 2: C3, C4, C9, C10 and region

3: C7, C8, C11, C12) with two transition zones (A: between regions 1 and 2; B: between regions 2 and 3). The cameras were set up to record the entire running track (Figure 1).

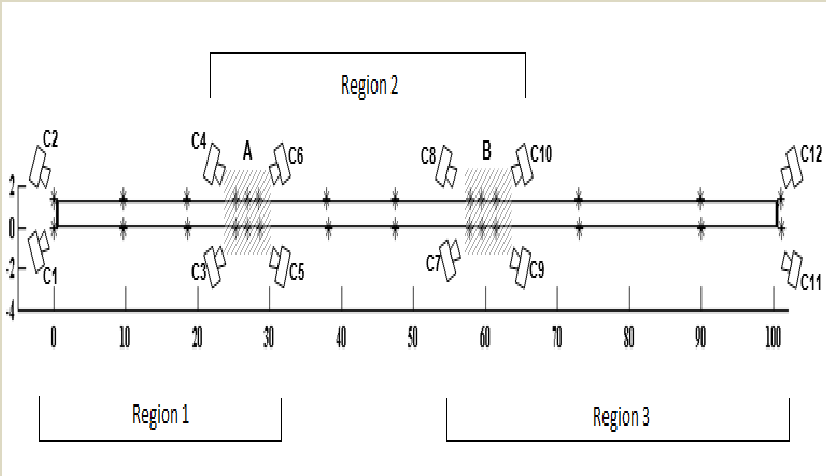

Figure 1: Camera positioning (C_n: n = 1, .., 12) to cover regions 1–3 of the 100 m track. The hatched areas show the two transition zones A and B between regions. (*) Twenty eight control points

The DVideo kinematic analysis system (Figueroa, Leite & Barros, 2003) was used to obtain the three-dimensional (3D) data. The cameras were calibrated using the direct linear transformation method (Abdel-Aziz & Karara, 1971). Twenty-eight control points were placed along the running track. One calibration stick with five control points was placed at each control point.
The system references (X: horizontal axis, Y: lateral axis, and Z: vertical axis) consisted of an acquisition volume with dimensions of 110 m (length) × 1.37 m (width) × 2.32 m (height). The 3D data were smoothed with a zero-phase forward and reverse fourth-order Butterworth digital filter and a cutoff frequency of 10 Hz.

Data Processing: The running velocity was derived from the obtained position data of the center of mass (horizontal axis) for each athlete. The horizontal velocity was calculated from the mean velocity over different segments of the track (0–20, 20–40, 40–60, 60–80, and 80–100 m) of the five athletes.
The angle of attack of the center of mass was determined by the angle between the vertical axis and the vector of the center of mass at the moment of touch-down (start point of contact of fifth metatarsal) for steps by different sides during the same run.
The horizontal velocity data and attack angle were described by the mean and standard deviation. The Lilliefors test ($P < 0.05$) was used to test the normality of the distributions. A logarithmic transformation was performed on the non-normal data ($y' = \log y$). The Student's t-test ($P < 0.05$) was used to compare laterality (right and left sides), and Pearson's correlation coefficients (R, $P < 0.05$) were used to measure the degree of association between the horizontal velocity and attack angle.

RESULTS AND DISCUSSION: The angle of attack of the center of mass varied along the 100 m dash owing to changes in the velocity and body posture, which agrees with the results of other studies (Kugler & Janshen, 2010). This change is due to the decreasing inclination of the body in relation to the vertical axis; thus, the attack angle tends to change according to the dynamics of the race.
The data presented statistically significant differences ($P < 0.05$) between the angles for the right and left sides during sprinting: the attack angle was lower on the right side than on the left side at the moment of takeoff.

Table 1 presents the mean and standard deviation of the horizontal velocity and angle of attack over each distance split. The mean horizontal velocity increased until it reached its maximal at the 40–60 m distance, while the angle of attack decreased throughout the run. Knuesel, Geyer, and Seyfarth (2005) found that increasing the horizontal velocity during sprinting produces flatter angles of attack; this result agrees with mechanical models and simulations of walking and running. The results of the present study showed that the body posture changed after touch-down based on the angle of attack, which tended to decrease with increasing horizontal velocity.

Table 1: Mean and standard deviation of variable angle of attack of center of mass for right and left sides and horizontal velocity split by distance.

Distance	Velocity [m/s]	Angle right [°]	Angle left [°]
0-20 m	6.25±2.55	39.05±13.14	50.48±10.55
20-40 m	9.53±0.38	38.45±9.27	49.28±10.31
40-60 m	9.70±0.36	36.18±6.55	46.40±7.07
60-80 m	9.57±0.36	37.06±6.82	44.17±3.53
80-100 m	9.39±0.36	36.64±6.04	43.35±3.20

The inverse relationship between the horizontal velocity and angle of attack is expressed by the Pearson's correlation coefficients (R). The increased horizontal velocity was more strongly associated with the angle of attack of the right side (R= -0.7481) compared to that of the left side (R = -0.5829). Thus, the lower angle of attack of the center of mass at touch-down is related to the increased horizontal velocity; this inverse relationship was also observed over 100 m dash.

The results show the variability of the angle of attack as associated to the horizontal velocity, and the differences considering laterality (right and left sides). The horizontal velocity interferes with the body posture of the athlete; the angle of attack becomes more flat in reference to erect postures. This information may help coaches with training strategies and understanding how the horizontal velocity can interfere with movement patterns.

CONCLUSION: This study analyzed the relationship between the angle of attack of the center of mass and the horizontal velocity over a 100 m dash in a training situation on an outdoor track. The inverse relationship between variables suggests that the body posture changes when an athlete reaches high velocity. In sprinting, the horizontal velocity is an important performance variable, and its association with movement patterns should be studied to improve the technical features of a race.

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